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MEASUREMENT OF MERCURY VAPOR PRESSURE BY MEANS
OF THE KNUDSEN PRESSURE GAUGE

BY

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THESIS

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IN PHYSICS

IN

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1921



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UNIVERSITY OF ILLINOIS
THE GRADUATE SCHOOL

April 30, 1921

I HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER MY
SUPERVISION BY CHARLES FRANCIS HILL
ENTITLED MEASUREMENT OF MERCURY VAPOR PRESSURE BY MEANS
OF THE KNUDSEN PRESSURE GAUGE
BE ACCEPTED AS FULFILLING THIS PART OF THE REQUIREMENTS FOR
THE DEGREE OF DOCTOR OF PHILOSOPHY IN PHYSICS

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TABLE OF CONTENTS

I.	INTRODUCTION	1
II.	HISTORICAL.....	2
	1. Dalton	2
	2. Avogadro	2
	3. Regnault	3
	4. Hertz	3
	5. Van der Plaats	4
	a. Table I	
	6. Hagen	5
	7. Ramsey and Young	6
	8. Morley	6
	9. Knudsen	7
	10. Comparison of Previous Methods	9
III.	EXPERIMENTAL	
	1. Description of Apparatus and Method	10
	2. Discussion of Accuracy of Method	14
	3. Comparison with Previous Methods.....	15
	4. Data - Tables II to IX	17
	5. Curves	24
IV.	CONCLUSIONS	28

I. INTRODUCTION

Within the last thirty years, a large amount of research has been done in partial vacua requiring an accurate knowledge of the gas pressure. Mercury and oil pumps have been used in the production of these vacua, and the gas pressure has been measured by means of the McLeod gauge. Now the total gas pressure must necessarily include the vapor pressures, and as is well known, the McLeod gauge does not measure vapor pressure. Liquid air or other cold agents are usually applied to remove vapors. Often several hours are required to do this, due to the fact that large quantities of vapor are absorbed by the walls of the container. In the case of mercury and vacuum oils a free surface is usually exposed to the vacuum and hence only an equilibrium condition between evaporation and condensation can be reached. It has been found in the present experimental work that this equilibrium condition may be as much as one-third or even two-thirds of the saturation pressure, depending upon the amount of surface exposed. Experimenters, generally, have probably not realized the difficulty of removing all vapors. If the saturation pressures of these vapors are accurately known, especially for mercury, it would be of value in vacuum experiments. Most of the published data on the vapor pressure of mercury at temperatures ranging from 0° to 50° is merely extrapolated from values at high temperatures. Only three direct methods have been used over the range 0° to 50° , and these show a lack of agreement, the variations being a large percent. The methods employed are also open to question due to evident sources of error. Because of the meagerness of the data, and the lack of agreement between the different observers, it was decided to attempt a redetermination of the vapor pressure of mercury

between the temperatures of 0° and 40°C. The use of the Knudsen pressure gauge was considered the most dependable method, since this instrument is independent of the gas and measures pressures of the order of mercury vapor. The results obtained with the instrument are given, following a brief review of the methods and results of previous observers.

II. HISTORICAL

That mercury has a vapor pressure was discovered about 1796 by investigators¹ in Holland. Dalton² also discovered the fact soon after and even made a few measurements at high temperatures before 1802. It was shown that mercury could be evaporated at fairly low temperatures but at temperatures of about 20°C, many thought that the vapor pressure was zero. In some experiments about 1834, Faraday placed some gold foil over mercury. The foil, in the course of a few hours disappeared, and in his explanation of the result, he attributed the effect as due to some sort of an affinity between the gold and the mercury and not to the evaporation of the mercury. This view that the vapor pressure was zero at low temperatures, seems to have been rather general until about 1850.

In 1833, using temperatures between 250° and 300°, Avogadro³ made measurements on the vapor pressure of mercury in a barometer tube. Using Dalton's equation, $P = ab^t$, he extrapolated back to 0°; however, over such a long range the extrapolation would have but little value, and it is now known that Dalton's equation does not

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1. J.R. Dieman, Van trost Wijk, Bondt. Chemische and Physische Oefanngen, 1897.
 2. Phil. Trans., 1826.
 3. Ann. de Pogg., 1833, T27, p 60.

hold except for the region in which its constants are determined.

Regnault⁴, using practically the same method, made measurements in 1862 at temperatures above 100°; he had, however, considerable trouble in getting readings at the lower temperatures. Regnault used the empirical equation of Biot,

$$\text{Log } P = a + bC^t + cK^t,$$

and extrapolated to 0°. His results over the range 0° to 40° are now known to be 10 to 100 times too large since values which he gives can be measured accurately by later methods.

About 1880, due to the invention of the Toepler and Sprengel air pumps and also the McLeod gauge, the question of the vapor pressure of mercury became of greater importance. Rood claimed .000002mm. for the Sprengel pump, and Hagen .00001 mm. for the Toepler pump. If mercury had an appreciable vapor pressure, this fact would have a decided influence upon the resultant pressures reached by the pumps.

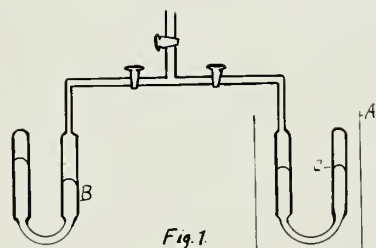


Fig. 1

Several investigations were carried out immediately and published between the years of 1880 and 1886. Among the first was that of Hertz⁵, his measurements being considered as among the more accurate ones made at higher temperatures. The apparatus

used, consisted of a differential manometer as shown in Fig. 1. The system was pumped out and closed. Then A was placed at the desired temperature, which caused a difference in level of the two arms of

4. Memoirs de l'Institute, 1862, T 26, p 506.

5. Wied. Ann., 15, Vol. 17, p 193.

the manometer C. By letting in air until the two arms of C balanced the vapor pressure of mercury could be read as the difference in the heights of the two arms of B. The temperature range was from 89.4° to 206° C. Hertz used the theoretical equation,

$$P = KT^{1-\frac{s-c}{A-R}} e^{-k/T} \quad \text{by means of which an}$$

extrapolation was made to zero. While the equation has some theoretical foundation, the constants are all calculated by applying the equation to the data, and all of the quantities become experimentally determined. Hertz took readings below 89.4° but did not consider them since his error was of the order of magnitude of the quantities measured. Even at 117° his error was 4% from the mean, and errors at the low points affect extrapolated values to a great extent, especially when the values sought are as small as those of mercury vapor, and the extrapolation is over a long range.

In 1886, van der Plaats⁶ published results by taking readings in the temperature range of 0° to 20° C, a region in which no other data had been taken except that of Hagen. While the percent error of his measurements is comparatively large, the data must be given considerable weight since the method was direct. Values from his mean curve have been given preference in tables, probably due to the fact that the method was direct. Van der Plaats' obtained his readings by passing dry gas through water, through sulphuric acid, and then through mercury until saturated, after which the mercury was collected by means of gold and pumice stone. The amount of water and mercury collected was weighed. Knowing the volume, temperature, and pressure of the gas, and the vapor pressure of water he could calculate

6. Rec. Trans. Chim. 5, p 49, 1886.

vapor pressure of the mercury. Van der Plaats' readings show considerable variation, nevertheless they are consistent enough to indicate that the order must be correct. The readings are given below.

Temperature	Pressure			
0°	.00042	.000515	.00048	.00044
4°	.00058			
7°	.00071			
9°	.00073			
10°	.00077	.00084	.000795	
11°	.00083			
12°	.00101	.00058		
13°	.001			
14°	.00101	.00099		
16°	.00115			
18°	.00133			
20°	.00133			

It is readily seen that if two or three values are omitted the others fall within $\pm 15\%$ of the mean curve. His error could be accounted for by the small quantities of collected mercury that he had to measure. Otherwise, the method seems difficult to criticise; however, it should not give values too high.

In 1882, Hagen⁷ published results which he got by taking readings between 0° and 200°, in 50°

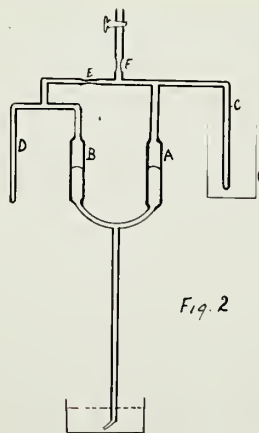


Fig. 2

steps. The apparatus is shown in Fig. 2. The system was pumped while heating in order to rid the walls of vapors and gases, after which the mercury was admitted through the capillary at the bottom. After the pressure had come into equilibrium, the tubes at the points E and F were sealed off. The mercury then stood

7. Wied. Ann., 1882, Vol. 16, p 610.

at the same level at A and B. By raising the whole apparatus to a temperature, T , the space above the mercury became saturated with vapor. If C was now placed in carbon dioxide snow and ether, Hagen thought that all of the vapors would be removed and the difference in pressure read between the heights of the two branches, A and B, would thus be the vapor pressure of mercury. This difference was read by means of a cathetometer. What Hagen measured, of course, was an equilibrium condition between evaporation and condensation. His values should therefore be too low. However, his results, like those of Regnault, are 10 to 100 times too high. His data also increases about 20% from 0° to 20° and 46% from 90° to 100° , while vapor pressures, as is well known, should have a decreasing percent increase as the temperature increases.

Another important set of data, that of Ramsey and Young⁸, was published in 1886. The relation of the absolute temperatures of water and mercury for which the two have the same vapor pressure, is well enough known so that if a few values are determined the ones between may be calculated. They applied this principle, getting readings from 135° to 520°C. , and then extrapolated to zero, using Regnault's equation. At the high temperatures, the results of Ramsey and Young and those of Hertz agree very closely. Ramsey and Young, however, used a much greater temperature range, and thus their data should give a more accurate extrapolation.

In 1904, E.W. Morley⁹ used a method similar to that of Van der Plaats, except that the evaporated mercury was determined by weighing the whole mercury sample before and after evaporation, and

8. Journal Chem. Soc., 1886, 49, p 37.

9. Phil. Mag., 1904, p 662.

the difference taken. He made determinations at temperatures 16°, 30°, 40°, 50°, 60°, and 70°, and calculated a mean curve by means of Dalton's formula,

$$P = ab^t.$$

Morley's readings at 16°, 30°, and 40° are from 8% to 20% below his mean curve, hence it appears that his extrapolated values can not be depended upon to be so very accurate. Again, the uniform slope of the curve is not in agreement with what one would expect for vapor pressure curves; however, the small amount of data and the variation of the lower points could easily account for this. The variation at the low temperatures is not surprising if one considers that he must detect a loss of 4.5 mg. of mercury from a large sample of mercury, even after a run of 13 days.

The last data of importance published was that of Knudsen¹⁰ in 1909. Knudsen first developed an equation¹¹ for the flow of a gas through a tube in a time t . Later, this equation¹² was extended to the case of a tube with a plate over one end, the plate containing a small opening so that the resistance to flow was mostly at the opening. His equation is as follows,

$$G = \sqrt{\rho} \frac{P' - P''}{W_1 + W_2} t,$$

where G is the mass of gas that passes through, ρ is the density at the temperature considered, P' and P'' are the pressures at the ends of the tube, W' and W'' are the resistances of the tube and opening, and t is the time. W' and W'' are calculated from dimensions and are gotten from theoretical considerations. Apparatus, based upon the

10. Ann. der Physik, 1909, 29, p 179.

11. Ann. der Physik, 1908-9, 28, p 75.

12. Ann. der Physik, 1908-9, 28, p 999.

above theory was then developed by which the vapor pressure of mercury could be determined. This apparatus is shown in Fig. 3. A glass

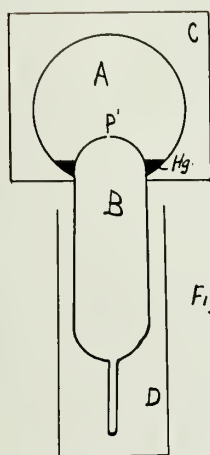


Fig. 3.

tube with mercury placed as shown is evacuated and then sealed off. The small opening is placed between the two compartments, A and B. A is placed in a temperature bath while B is kept at a low temperature by means of carbon dioxide snow and benzol. P'' , the pressure in B, is considered zero since the vapor pressure of mercury at this low temperature would be negligible. The mass of vapor that passes through in a time t is then measured. In the equation, the pressure P' is considered that at the opening and to be the vapor pressure of

mercury, and can be calculated if W' and W'' are known. Readings from 0° to 154°C were taken.

A criticism of this method should include a criticism of both the theory and the experimental method. With the weight of evidence of other methods indicating that his results are too low, the equation should certainly be tested further before great weight can be given to the results. The method tends to give values too low. An appreciable time is required for mercury to evaporate, and since P' is continually being relieved, this would tend to give a value below that of the saturation pressure. Any residual gas in the tube would also hinder diffusion and thus lower the calculated value.

All other values, except the extrapolated values of Hertz, are far above those of Knudsen over the range from 0° to 20°C . Knudsen's curve has the greatest slope of any other investigator,

and, although lowest at 0° is highest at 154°, his highest temperature measured.

In order to compare results, the following table is given.

Pressure is expressed in millimeters of mercury.

TABLE I

T	Regnault	Hagen	Hertz	Ramsey Young	Van der Plaats	Morley	Knudsen	Hill
0°	.02	.015	.00019		.00047	.0004	.000184	.00035
10°	.0268	.018	.0005		.0008	.0008	.0005	.000775
20°	.0372	.021	.0013		.0013	.0015	.00118	.00132
30°	.053	.026	.0029			.003	.00273	.00407
40°	.0767	.033	.0063	.008		.006	.006	.00787
50°	.112	.042	.013	.015		.011	.0126	.00800
60°						.021		
70°						.04		

Regnault's and Hagen's data agree fairly well, but both are now known to be too high since values as large as they give could be readily measured by later methods. At higher temperatures of 100° and above, the results of Ramsey and Young, and those of Hertz differ by only a small percent, and either is probably within a small percent of the correct values at those high temperatures. Hertz discarded his readings below about 30° because his error was large compared to the magnitude measured. Errors in his lowest temperature readings would affect his extrapolated values to a large extent. Ramsey and Young used a wider temperature range but their lowest point was 135°C., which gives them a longer extrapolation. The weight of the two sets of data would probably be about the same.

Knudsen used a direct method over a range from 0° to 154° and obtained consistent results. His data also agree with the extrapolated values of Hertz. However, his method would tend to give values too low. The methods of Morley and van der Plaats, would also be expected to give results too low if in error, and yet they are about two or three times as high as Knudsen's, and agree fairly

well with each other, and with the results of Ramsey and Young and with the data taken in the present experimental work. While van der Plaats and Morley can not claim a high percent of accuracy due to the error in observations, yet their method would not be expected to be in error by as much as Knudsen's data indicates.

The conclusion from the above discussion is, that the weight of experimental evidence seems to indicate that the correct values for the vapor pressure of mercury are probably of the order of the data taken by Morley and van der Plaats.

III. EXPERIMENTAL

After noting the disagreement of previous observations, it is evident that a set of measurements by a direct and dependable method at ordinary working temperatures would be worth while. The Knudsen¹³ pressure gauge, if accurately calibrated, will give consistent and accurate readings on pressures of the magnitude of mercury vapor and has been used as low as 10^{-8} mm. The instrument may be used as an absolute manometer; however, the one used in this case was not arranged to be used in this manner, hence it was necessary to calibrate it by means of some other gauge. The principle upon which it depends is that if a strip of platinum, say, is heated in a partial vacuum, the molecules of the residual gas will become heated by contact with the strip and fly off. If a vane free to turn is placed before the heated strip, these molecules will strike and turn the vane, if the mean free path of the molecules is greater than the distance between the vane and foil. The pressure is proportional to the number of molecules present and thus the deflection gives a measurement of the pressure. Now the deflection at zero pressure

13. Ann. der Physik, 1910, 32, 4, pp 809-42; Phys.Rev. 12, pp 70-80, 1918.

is zero, so if the pressures are read on another gauge and the deflections on the Knudsen gauge, curves may be drawn with the origin as an accurately determined point. This fact made it possible to use a McLeod gauge for calibration, since it may be read fairly accurately to about .0005 mm.

A special Pyrex McLeod gauge was made for the purpose. This was desirable since the rest of the apparatus was made of pyrex. The volume tube was made rather large so as to do away with friction and surface tension of the mercury as much as possible. The gauge would still read consistently to .0005 mm. if the mercury and glass were kept clean. The apparatus was connected as shown in Fig. 4. The Knudsen gauge, A, and the sample container, B. were fixed rigidly in a tight box at 1,2,3, so that the calibration would remain constant

and the temperature could be controlled. A tube led off to the liquid air trap, to the McLeod gauge and to the pump as shown. The pumping system consisted of a Langmuir condensation pump in series with Gaede Rotary oil and mercury pumps. With all of the vapors removed and kept from the Knudsen gauge by means of liquid air on the trap, C, the pressure was made about .005 mm. and

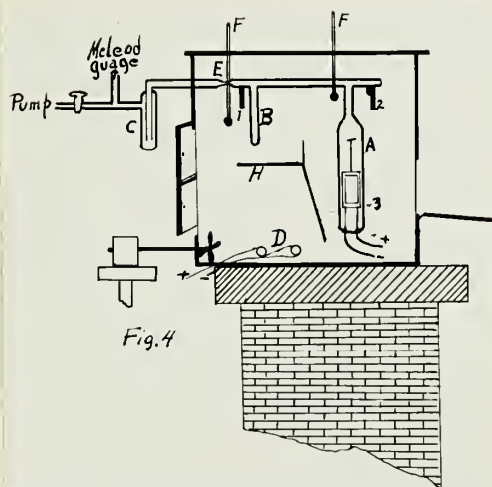


Fig. 4

then by reducing the pressure in steps, reading the pressures on the McLeod gauge and the deflections on the Knudsen gauge, a set of calibration curves was drawn for the currents .3, .4, .5 and .6 amperes flowing through the platinum strip. In order to gain

accuracy, the curves were drawn on 40 cm. co-ordinate paper. Practically all of the points fell accurately on the curves, showing that the McLeod gauge was consistent at least. (See Fig.5 and 6.)

The sample of mercury was then introduced into the container and with liquid air on the trap and pumps running, the mercury was distilled out of the container to the walls of the tube and back again by heating slowly. This process of distillation was carried out a number of times. Then with warm water on the sample, the whole tube was heated to a temperature of 250° to 300°C . for several hours, to drive the vapors and absorbed gases out of the walls of the tube. The apparatus was then sealed off at E. The vapor pressure of mercury at any temperature may be gotten by allowing the system to reach a constant temperature for a time, taking the total pressure, and then, after driving in all of the vapor by heating, with liquid air on the sample container, measure the residual pressure.

The difference between the total and residual pressures is the vapor pressure of mercury. In this way readings were taken at a number of temperatures between 0° and 35°C ., and the tube was again opened and the same process of distillation and heating carried out and the tube sealed off again. This process was continued until minimum values for the vapor pressure of mercury were obtained on three successive sets of readings. It was thought that the mercury could be considered pure at this point. Another calibration of the gauge was now carried out and a second sample of mercury purified with nitric acid was introduced and the process of distillation and heating repeated. The readings on this sample checked within a small percent of the three readings on the first sample. Of the four sets

of data, one or two points differ from a mean curve by about 6%, the rest are all within $\pm 3\%$, which is about the accuracy one would expect from the method, as will be shown later.

Using the above method, the vapor pressure of mercury was measured at nineteen points between the temperatures of $-.7^{\circ}$ and 34.9°C . The temperature was measured by means of two tenth-degree thermometers, placed at different points in the box. To insure a uniform temperature, the air was circulated by a fan within the box but driven by a motor outside, the whole fan system being entirely disconnected from the box and the pier supporting it. This was necessary to prevent jarring of the Knudsen gauge. Baffles, H, were introduced to direct the circulation of the air.

The regulation of temperature was easily accomplished. For those above room temperature, two heating coils, D, were used, through which the current could be controlled. For those below room temperature, the window was opened and an electric fan made to blow air on the box, $-.7^{\circ}$ being reached in this way, the unusually warm winter preventing lower temperatures. An attempt was made to control the low temperatures by turning the nozzle of a carbon dioxide tank into the box but this lacked constancy. In general the temperatures were held very constant, probably to within $\pm .1^{\circ}$, or at most to $\pm .2^{\circ}$. If the thermometer changed as much as .2 the change was detected on the Knudsen gauge; and it is doubtful if the apparatus would change as readily as the thermometers.

The Knudsen gauge was read by means of a lamp and scale at about one meter distance. In order to hold the zero point, or rather to hold the vane and foil at constant distance, the scale was rigidly fixed to the floor. Whenever the vane became displaced, it could be

brought back to its zero point by merely restoring the zero point of the scale. One set of calibration curves was used for three sets of data, and between each set the calibration was checked, so that it was known to remain constant.

Before comparing the present data with that of former observers, it would probably be best to consider some of the sources of error in this research and their magnitudes. In the first place the method would be expected to give values too high, since all impurities would tend to increase the vapor pressure in the tube. Hence, the first sample of mercury was distilled more than twenty times in a vacuum, probably 95% of the sample being lost. The second sample was first treated with nitric acid and then distilled 8 times with the pump running. The data on it checked within a small percent of the mean curve of the first sample. This indicates that the error due to other vapors was negligible. It was thought that the sample container, cooled to the temperature of liquid air, might absorb some of the residual gas, but this point was tested before the sample was introduced and no effect detected.

Special care was taken to keep the mercury and the glass of the McLeod gauge clean to prevent friction. It was found that upon taking several readings at the same pressure, the gauge could be read within $\pm 2\%$ except at the low pressures and these seem to check well with the higher readings as shown by the curves. The accurate point at the origin helped to take care of such errors. The readings of the Knudsen gauge differ over a range of two or three percent however, much of this is due to the fact that the readings were taken from curves and a range of about one percent could be obtained by drawing a new curve for the same points. Hence, the error of the

Knudsen gauge was apparently within $\pm 2\%$. The temperature readings apparently did not introduce an error larger than 2% , since the Knudsen gauge would detect small changes. The total error, therefore, is within $\pm 6\%$. The fact that this is about the variation of the individual readings from the mean curve, indicates that the principle sources of error have been accounted for, and that the accuracy of the data is what one should expect from the method employed.

The actual readings are given on the following pages, beginning with Table II. The two sets of calibration curves are shown in the form of curves in order to show how the readings fit the curves. The values determined for the vapor pressure of mercury are shown in Fig.7, a smooth curve is drawn through the points. The values for each 2° , beginning with 0°C and taken from the mean curve are given in Table IX. .

In order to compare results with those of former methods, Table I and the mean curves of Fig.8, will be referred to. The data for all methods is given in 10° intervals. In the first place, if the slope of the curves is considered, the percent increase should decrease as the temperature increases. The slope of the present data as measured in this way, is about a mean of the slope of other methods. Van der Plaats' curve has such a slight rise from 0° to 20° that if it is extrapolated above 20° it will not agree with other methods. This may be accounted for by the variations of his observations. Morley's curve rises faster but the low values at 16° , 30° , and 40° , would make his curve too low in that region. The slope of the present data is greater than that of Morley's and agrees with Ramsey and Young. The methods of Morley and van der Plaats should tend to give values too low, while the present method should give

values too high if in error, and yet the three agree fairly well and with that of Ramsey and Young. On the other hand, Knudsen's method would tend to give values too low, and it does not seem probable that the other three methods could be in error as much as indicated by Knudsen's data. His results are approximately 50% lower over the interval 0° to 20°C .

TABLE II

First set of calibration data

Pressures read on the McLeod gauge, and deflections on
Knudsen gauge. Shown graphically in Fig.5

I	R_0	R	Deflection	McLeod Pressure	Mean
.3	10.0	14.71	4.71	.005	.005
.4		18.04	8.04	.005	
.5		22.02	12.02	.00495	
.6		26.4	16.4	.00498	
.3	10.0	14.1	4.1	.004	.004
.4		16.98	6.98	.004	
.5		20.41	10.41	.004	
.6		24.15	14.15	.00395	
.3	10.0	12.98	2.98	.0026	.00256
.4		15.2	5.2	.00255	
.5		17.81	7.81	.00255	
.6		20.7	10.7	.0025	
.3	9.8	11.96	2.16	.0016	.0016
.4		13.6	3.8	.0016	
.5		15.4	5.6	.0016	
.6		17.48	7.68	.00155	
.3	9.7	10.8	1.1	.00075	.00071
.4		11.6	1.9	.00072	
.5		12.58	2.88	.00067	
.6		13.62	3.92		

TABLE III

Data for the determination of vapor pressure of mercury at various temperatures as read by the Knudsen Gauge

First Run

I	R ₀	R	Total Pressures		Mean	Temperature
			Deflection	Pressure Curve		
.3	10.1	13.0	2.9	.0024	.002355	23°
.4		15.1	5.0	.00237		
.5		17.45	7.35	.00235		
.6		20.	9.9	.0023		

Residual Gas Pressure

.3	9.82	10.05	.23	.00012	.000115	
.4		10.15	.33	.00012		
.5		10.3	.48	.00011		
.6		10.5	.68	.00011		

Total Pressures

.3	10.25	14.5	4.25	.00422	.00416	23.9°
.4		17.5	7.25	.00422		
.5		20.9	10.65	.00416		
.6		24.5	14.25	.00407		

.3	10.45	14.05	3.6	.00328	.00323	26.8°
.4		16.65	6.2	.00328		
.5		19.55	9.1	.00324		
.6		22.65	12.2	.00314		

.3	10.4	13.32	2.92	.00242	.00239	22.8°
.4		15.46	5.06	.0024		
.5		17.85	7.45	.00237		
.6		20.4	10.0	.00235		

.3	10.15	15.52	5.37	.00694	.00584	34.9°
.4		19.22	9.07	.00608		
.5		23.4	13.25	.00575		
.6		28.0	17.85	.0056		

.3	10.32	11.7	1.38	.0009	.000895	11.8°
.4		12.65	2.33	.00088		
.5		13.86	3.54	.0009		
.6		15.15	4.83	.0009		

.3	10.68	11.7	1.02	.00062	.00063	5.8°
.4		12.4	1.72	.00064		
.5		13.25	2.57	.00062		
.6		14.2	3.52	.00063		

.3	10.1	12.6	2.5	.00196	.00195	20.3°
.4		14.5	4.4	.00196		
.5		16.6	6.5	.00194		
.6		18.9	8.8	.00194		

TABLE III (Continued)

The apparatus was heated to 100° for a short time with liquid air on sample container to drive in mercury and the following residual pressures at 24.2°C. taken

I	R ₀	R	Deflection	Pressure Curve	Mean	Temperature
.3	10.25	10.4	.15	.00008		
.4		10.5	.25	.00009		
.5		10.62	.37	.000088		
.6		10.75	.5	.00008	.000085	

Applying Charles Law, the residual pressure at various temperatures was calculated

5°	.00008
10°	.0000812
15°	.0000825
20°	.0000838
25°	.000085
30°	.0000865
35°	.000088

TABLE IV

Second Run of Data.

I	R ₀	R	Deflection	Pressure Curve	Mean	Tempera- ture
.3	9.5	12.44	3.94	.00245		23°
.4		14.55	5.05	.0024		
.5		16.9	7.4	.00234		
.6		19.6	10.1	.00236	.00239	
.3	9.7	11.25	1.55	.00103		13°
.4		12.35	2.65	.00103		
.5		13.55	3.85	.00100		
.6		14.9	5.2	.00098	.00101	

Heated to 120° with liquid air on container
and the following residual pressures
taken.

.3	9.75	9.83	.08	.00005		23°
.4		9.86	.11	.000046		
.5		9.9	.15	.000043		
.6		10.0	.25	.00004	.000044	

TABLE V
Third Run of Data

I	R ₀	R	Deflection	Pressure Curve	Mean	Tempera- ture
.3	9.8	13.0	3.2	.00277	.00275	25°
.4		15.3	5.5	.00274		
.5		18.0	8.2	.00276		
.6		20.9	11.1	.00272		
.3	10.0	14.32	4.32	.00432	.00427	30.8°
.4		17.3	7.3	.00438		
.5		20.7	10.7	.00422		
.6		24.5	14.5	.00416		
.3	10.0	15.0	5.0	.0055	.00540	34.3°
.4		18.55	8.55	.00556		
.5		22.5	12.5	.0054		
.6		26.75	16.75	.00514		
.3	9.7	11.05	1.35	.00087	.00088	11.6°
.4		12.02	2.32	.00088		
.5		13.19	3.49	.00089		
.6		14.5	4.8	.00088		
.3	10.2	10.8	.6	.00033	.00035	-.7°
.4		11.17	.97	.00036		
.5		11.7	1.5	.00036		
.6		12.35	2.15	.00036		
Residual Pressure						
.3	10.15	deflection hardly preceptible			.00002	
.4		10.19	.04	.00002		
.5		10.23	.08	.00002		
.6		10.28	.13	.00002		

TABLE VI

Second Set of Calibration Data

I	R ₀	R	Deflection	Pressure (McLeod)	Mean	Temperature
.3	10.12	13.97	3.85	.0037	.003675	
.4		16.8	6.68	.00365		
.5		20.1	9.98			
.6		23.65	13.53			
.3	10.12	12.67	2.55	.002	.002	
.4		14.5	4.38	.002		
.5		16.78	6.66			
.6		19.16	9.04			
.3	10.12	11.8	1.68	.00105	.00108	
.4		13.08	2.96	.0011		
.5		14.5	4.38	.0011		
.6						
.3	10.09	11.7	1.08	.00068	.00064	
.4		11.97	1.88	.0006		
.5		12.89	2.8			
.6		13.9	3.81			

TABLE VII

Data on Second Sample

I	R ₀	R	Deflection	Pressure Curve	Mean	Temperature
.3	10.5	14.0	3.5	.00318	.00316	25.6°
.4		16.5	6.0	.00316		
.5		19.6	9.1	.00320		
.6		22.6	12.1	.00316		
.3	10.6	14.7	4.1	.00402	.00394	28.6°
.4		17.75	7.15	.00406		
.5		20.9	10.3	.00388		
.6		24.4	13.8	.00380		
.3	10.85	12.56	1.71	.00112	.00116	11.4°
.4		14.0	3.15	.00118		
.5		15.55	4.7	.0012		
.6		17.2	6.35	.00116		

Residual Pressure

.3	10.4	10.8	.4	.00023	.00024	
.4		11.1	.7	.00024		
.5		11.45	1.05	.00024		
.6		11.8	1.4	.00024		
.3	10.65	13.95	3.3	.0029	.00286	24°
.4		16.35	5.7	.00292		
.5		19.0	8.35	.00281		
.6		22.1	11.45	.00284		

Values for the Vapor Pressure of Mercury at Various Temperatures

Temperature	Pressure mm. mercury	Temperature	Pressure mm. mercury
- .7°	.00033	24.0°	.00262
5.8°	.00055	25.0°	.00273
11.4°	.00092	25.6°	.00292
11.6°	.00083	26.8°	.003145
11.8°	.000815	28.6°	.0037
13.0°	.00097	29.9°	.004075
20.3°	.00187	30.8°	.00425
22.8°	.00230	34.3°	.00538
23.0°	.00234	34.9°	.00575
23.0°	.00235		

TABLE IX

Values for Each 2° as Taken From Mean Curve

0.0°	.000350	22.0°	.00214
2.0°	.000412	24.0°	.00234
4.0°	.000487	26.0°	.003
6.0°	.000572	28.0°	.0035
8.0°	.000662	30.0°	.00407
10.0°	.000775	32.0°	.00467
12.0°	.000895	34.0°	.00535
14.0°	.00105	36.0°	.00607
16.0°	.00126	38.0°	.00695
18.0°	.00150	40.0°	.008
20.0°	.00182		

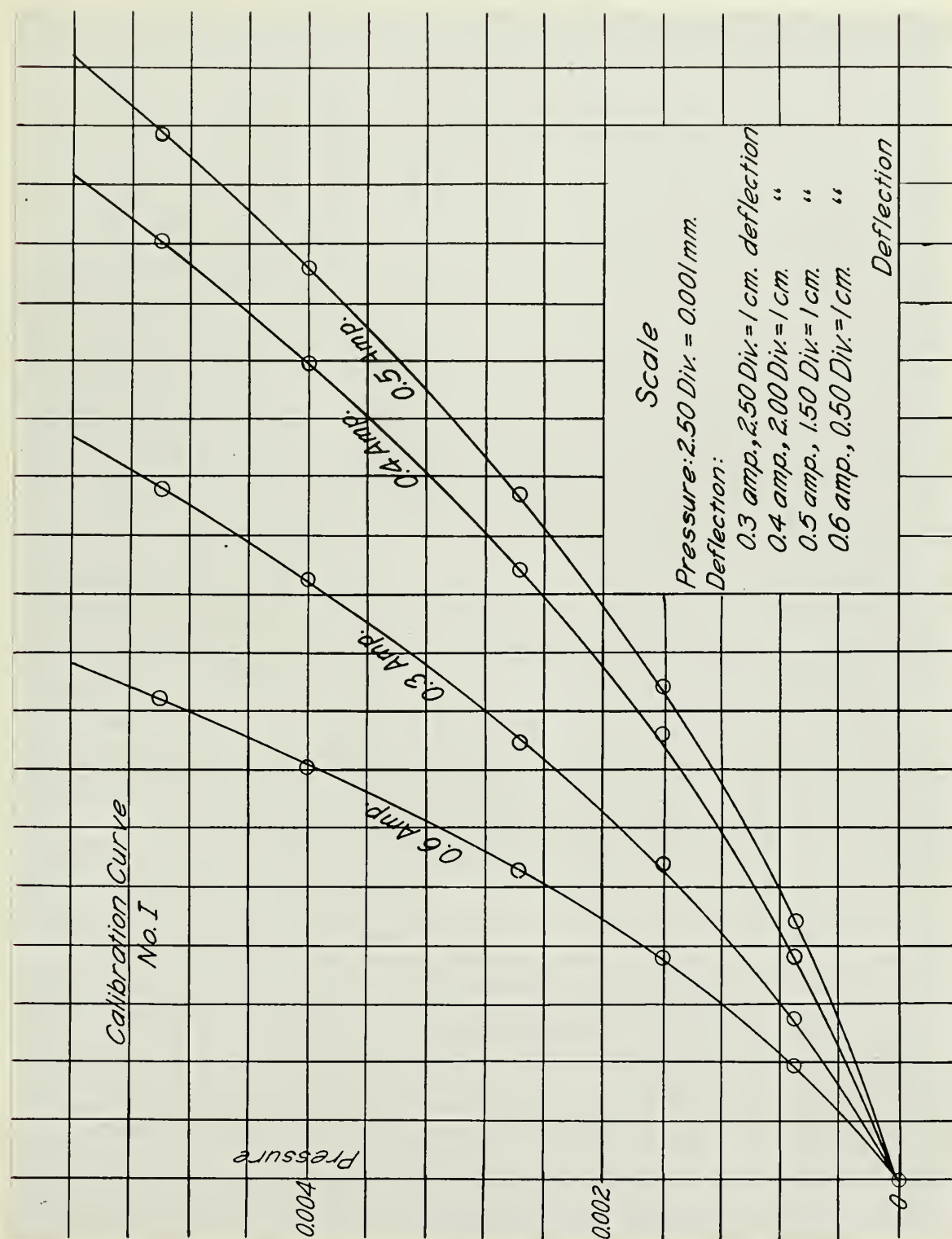
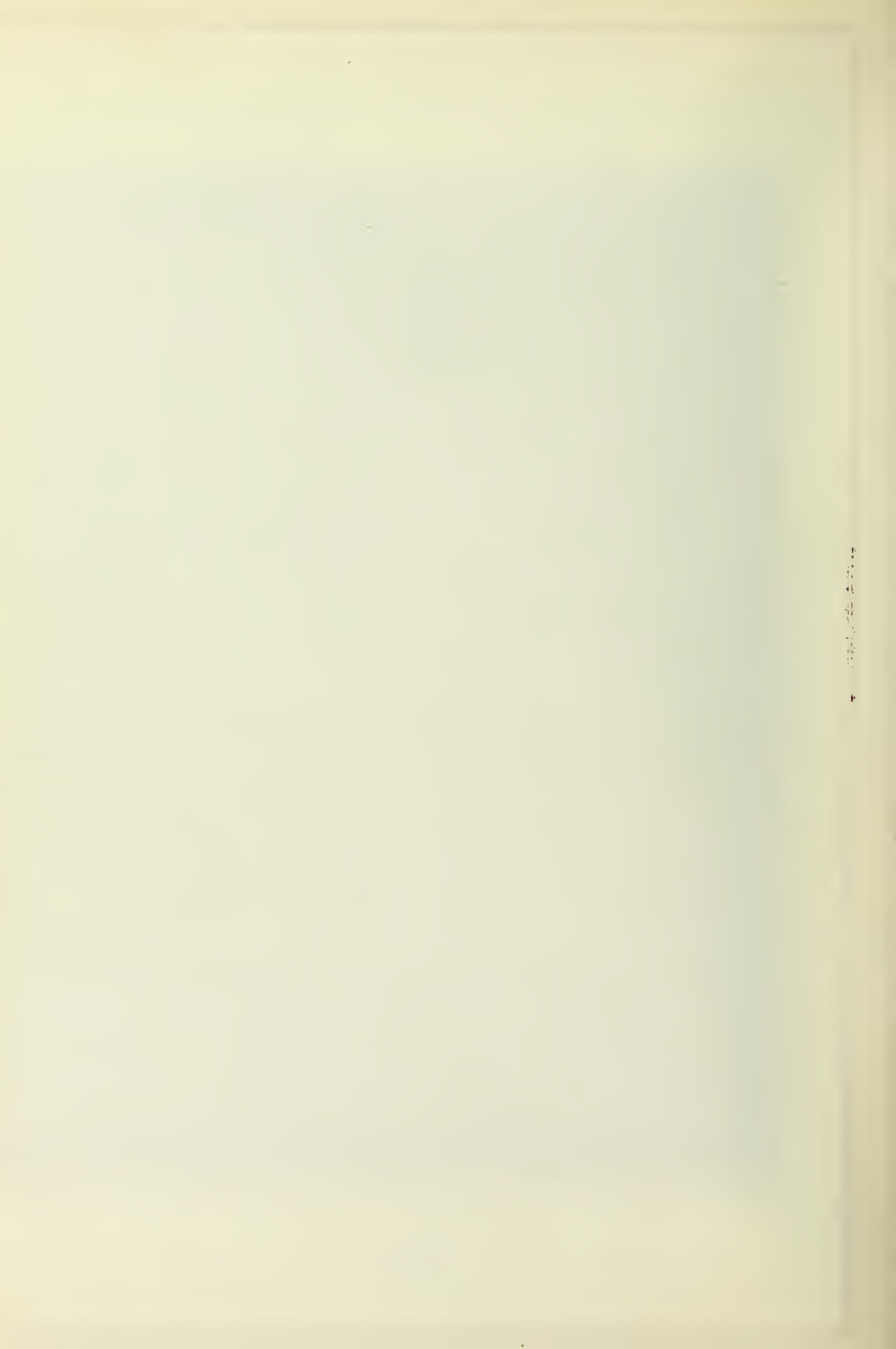


Fig. 5



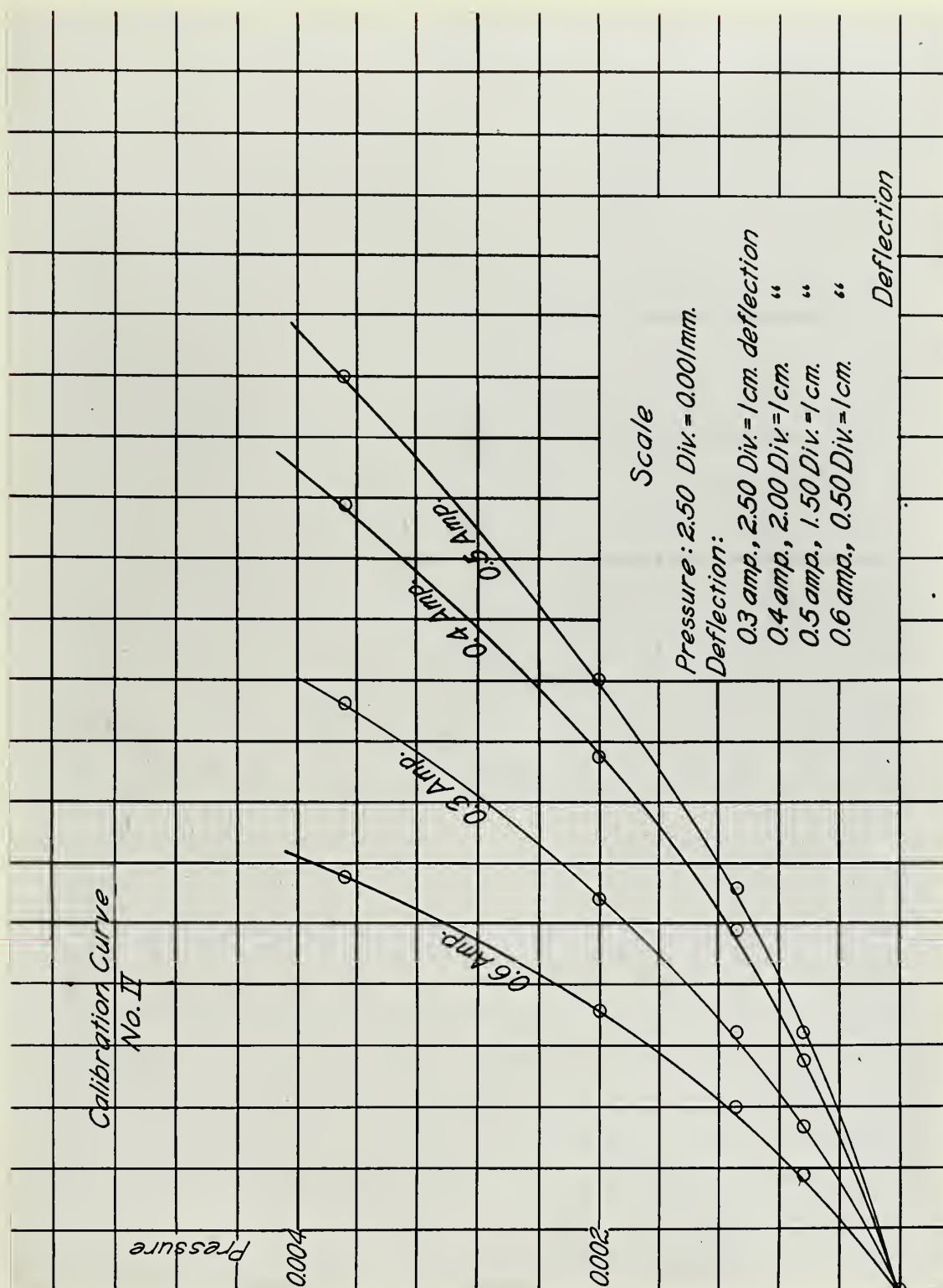


Fig. 6

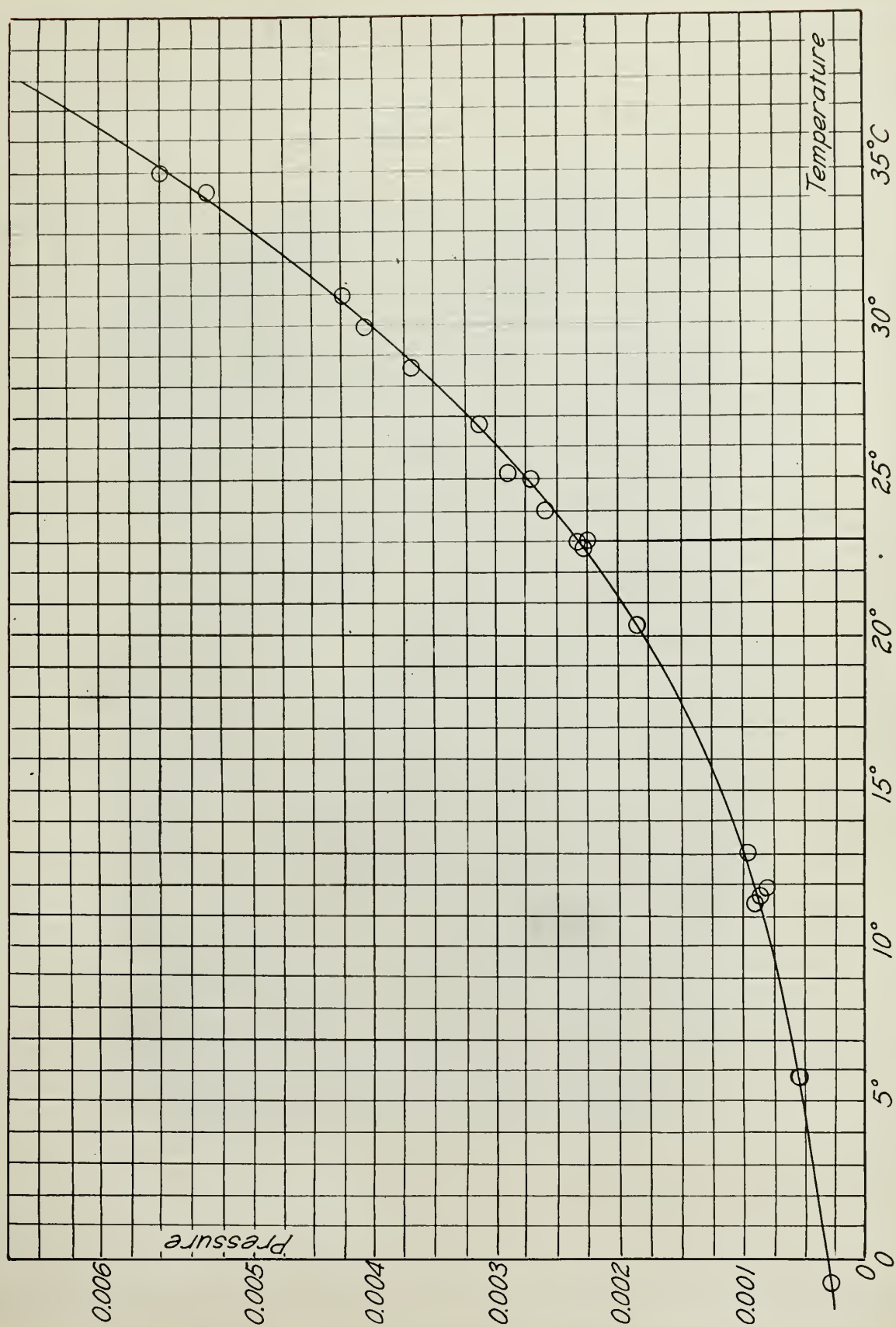


Fig. 7

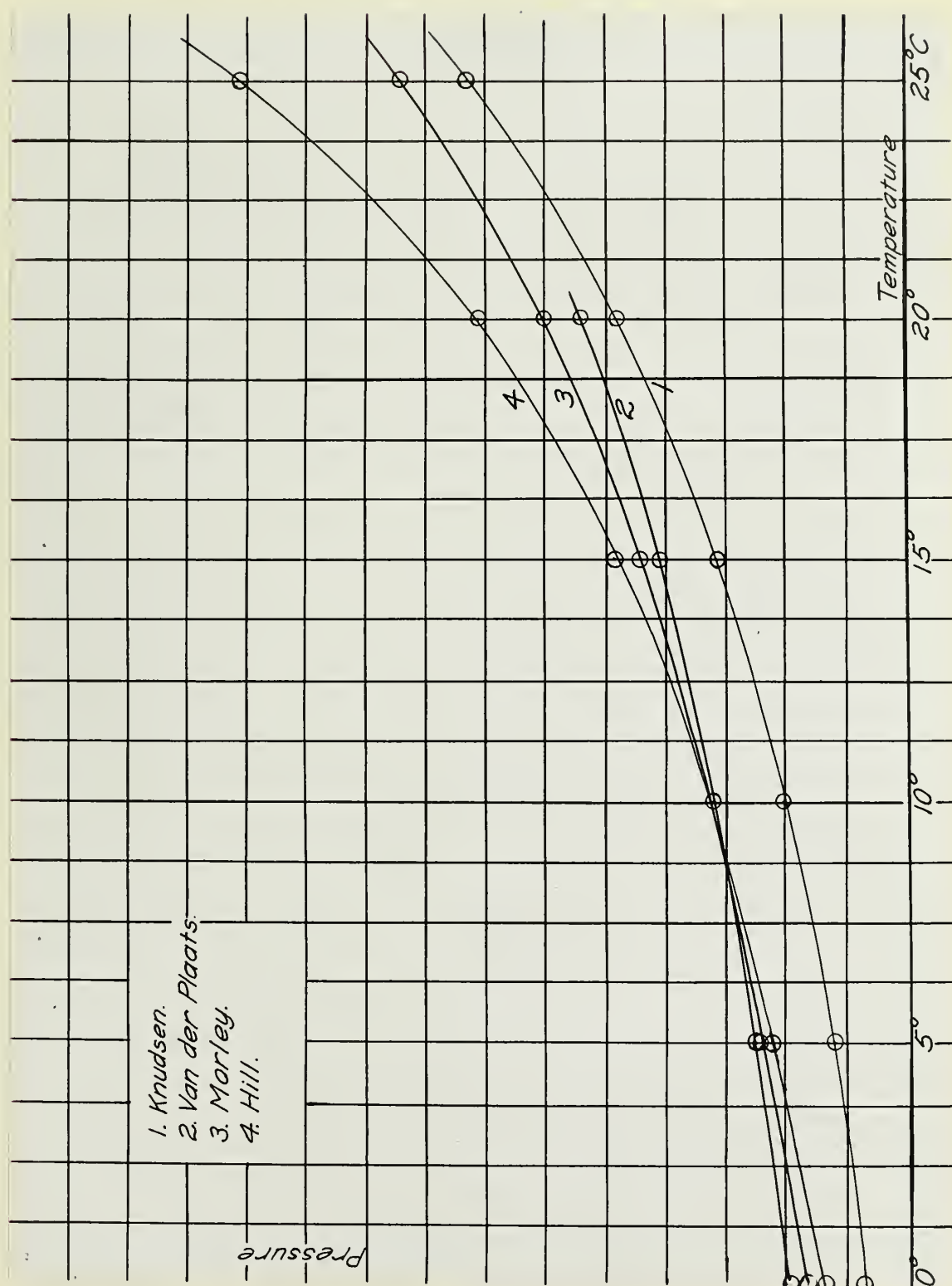


Fig. 8

IV CONCLUSIONS

The following conclusions may be drawn:

1. A direct method for the measurement of mercury vapor pressure has been employed in which advantage was taken of the present day methods of obtaining a high vacuum, and its measurement by means of the Knudsen gauge.

2. Nineteen readings on the vapor pressure of mercury have been taken between the temperatures of -7° and 34.9° Centigrade. These values lie within $\pm 6\%$ of a mean curve.

3. A criticism of the method indicates that it should not be in error by more than $\pm 6\%$, except for impurities and that these have been reduced to a minimum by the method of purification.

4. The order of the values obtained agrees fairly well with those of Morley and van der Plaats; however, the percent variation of the actual observations is much less in the present method.

5. The slope of the curve of the present data is about a mean of the slopes of other methods and agrees with that of Ramsey and Young extrapolated from higher temperatures.

In conclusion, I wish to thank Professor A.P. Carman for the use of the facilities of the laboratory, and Professor C. T. Knipp for the interest he has taken in the work and for the suggestions offered.

V I T A

Charles Francis Hill received his early education in the public schools of Illinois, and his college preparatory work in the Eastern Illinois State Normal School from which he graduated in 1911. He then entered the University of Illinois, from which he received the degree of A.B., in 1914. From 1914 to 1921 he has been an assistant in physics at the University of Illinois, doing part-time graduate work, having received the degree of M.A. in 1916.

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